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Commissioning and first on-line test of the new ISOLTRAP control system

C. Yazidjian[1,a], D. Beck[1], K. Blaum[1,2], H. Brand[1], F. Herfurth[1], and S. Schwarz[3]

[1] GSI-Darmstadt, Planckstraße 1, 64291 Darmstadt, Germany
[2] Institut für Physik, Johannes Gutenberg-Universität, Staudingerweg 7, 55128 Mainz, Germany
[3] NSCL, Michigan State University, East Lansing, MI 48824-1321, USA

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Abstract. A new versatile LabVIEW® based control system has been developed and implemented at the ISOLTRAP experiment. This enhances the ease of use as well as the flexibility and reliability for ISOLTRAP and is flexible enough to be used for other trap experiments as well.

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1 Introduction

The tandem Penning trap mass spectrometer ISOLTRAP [1,2], installed at the on-line isotope separator ISOLDE [3] at CERN (Geneva) is a facility dedicated to high-precision mass measurements on short-lived radionuclides. The mass measurement is based on the determination of the cyclotron frequency ν_c of ions manipulated by use of radio-frequency (rf) fields in Penning traps. With a charge to mass ratio q/m and a magnetic field B the relation is

$$\nu_c = \frac{1}{2\pi} \cdot \frac{q}{m} \cdot B. \tag{1}$$

A relative mass uncertainty of $\delta m/m \approx 10^{-8}$ is routinely reached with ISOLTRAP. These high-precision mass measurements contribute to fundamental tests like the unitarity of the Cabibbo-Kobayashi-Maskawa mixing matrix [4,5,6].

ISOLTRAP is a versatile experiment. It can manipulate and measure the mass the majority of radioactive ions produced at ISOLDE. The manipulation of the stored ions requires a reliable and fast control system, especially in case of short-lived nuclides with half-lives in the millisecond range. From the new general control system framework, CS, developed at DVEE/GSI, a dedicated control system for ISOLTRAP has been derived and implemented by adding experiment specific add-ons to the framework [7].

[a] e-mail: Chabouh.Yazidjian@CERN.ch

2 The ISOLTRAP experiment

The ISOLTRAP spectrometer is composed of three parts:

1) A linear radio-frequency quadrupole (RFQ) ion trap which has the task to stop, accumulate, cool, and bunch the 60 keV ISOLDE beam for an efficient transfer into the preparation trap.
2) A cylindrical preparation Penning trap filled with helium gas to prepare and mass separate [8] (resolving power $R = m/\Delta m$ up to 10^5) the ions coming from the RFQ and to bunch them for an efficient delivery to the second Penning trap where the mass measurement is performed.
3) A hyperbolical precision Penning trap to determine the cyclotron frequency ν_c (eq. (1)) of the ion of interest and of the reference ion.

In the precision trap, the experimental procedure for a mass measurement requires a scan of the frequency of the rf-field to excite the ion motion around ν_c. The duration of each frequency step varies from 0.3 to 1.5 s depending on the half-life of the ion of interest.

3 Design of the control system

3.1 Motivation

The old control system was based on a VME bus crate controlled via a Motorola processor E6 CPU using OS9. For more than a decade, it was successfully used, but the hardware has become outdated and not reliable any longer since no support was available. ISOLTRAP needs to remotely control more than 100 voltages (ion optics, trapping electrodes, etc.), the regulation of the buffer gas pressures, as well as 8 delay times and up to 10 different frequencies. The complex timing scheme, especially for short lived-ions needs the different steps to be synchronized with a precision of better than a 1 μs. Thus a modular control system with the ability to follow the growth of the experimental set-up in size and complexity was required.

3.2 The CS framework

The old VME based system was used to control the hardware devices and the measurement procedure. A Graphical User Interface (GUI) was operated from a PC connected to the VME-bus via TCP/IP to setup the measurement and display the on-line data. In spring 2003 a new control system has been implemented and commissioned. The GUI is reused as well as practically all existing hardware devices of ISOLTRAP whereas the VME-bus is replaced by a PC. Instead of trying to port the old system from VME to the new PC platform, the all-new object-oriented CS framework has been implemented [7] in about nine man months. It does not only replace the old system but provides more functionality that enhances the experimental capabilities of ISOLTRAP.

Figure 1 shows a simplified overview of the control system hierarchy. The hardware devices (rounded boxes) are represented by objects (boxes) which are organized in a corresponding package (shadowed boxes). The hardware devices, with number of modules used at ISOLTRAP in brackets, are addressed either by GPIB or OPC interfaces (not shown in fig. 1). In the Function Generator package, two different kinds of hardware are shown: DS345 from Stanford Research Systems and AG33250A from Agilent. Following the same principle, SR430 is a multichannel analyzer for data acquisition and Data Collector which collects and buffers data from acquisition devices. DF94011 is a programable delay box. The highlighted part with a darker grey box is experiment specific. The Sequencer (with the CycleControl and MassMeas) is the conductor of the control system. Once the user starts a measurement from the GUI, the Sequencer takes over the control of the experiment. It communicates with the other objects via events. The arrows show the communication paths between the objects (for better understanding the arrows target the package, but not the objects themselves).

Thanks to this object-oriented structure, a broken hardware device can be easily replaced by another one belonging to the same package. The only change in the CS is the one of the object associated to the hardware part. As an example of its flexibility, a DS345 function generator can be exchanged by a AG33250A in a few minutes without shutting down the CS nor the whole experiment.

4 Commissioning of the control system

The new control system was put into operation by late summer 2003, and after extensive off-line tests all the on-line radioactive beam experiments in 2004 were performed with it. In full operation, about 80 objects are required simultaneously for controlling the hardware. The control system runs stable for at least one week of operation.

With such a versatile concept, the easy maintenance of the new control system is one more advantage to add to those that allow higher stability and flexibility. Also enhanced is the comfortable handling by having a quick parameter setup feature for the requirement of high-precision mass measurements, especially for short-lived nuclides.

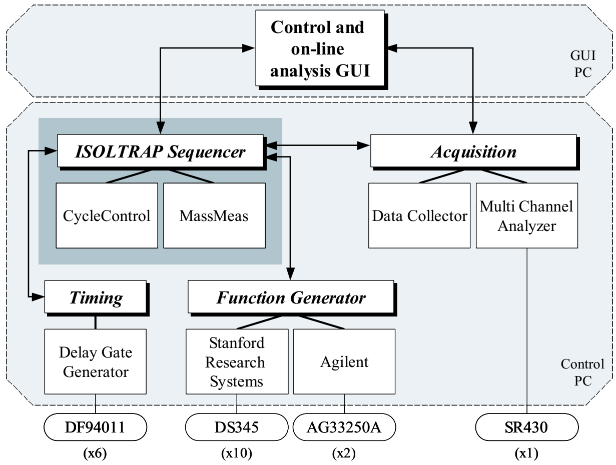

Fig. 1. Simplified sketch of the ISOLTRAP control system. Shadowed boxes represent a package of software modules (depicted by boxes) attached to their hardware component (rounded boxes). Arrows indicate the communication path. For more details see text.

5 Conclusion

The high-precision mass spectrometer ISOLTRAP needed a reliable and more convenient control system for its experimental data acquisitions. The new flexible CS framework fulfilled the requirement of this versatile apparatus and enhances the experimental capabilities of ISOLTRAP. During on-line runs the CS framework has shown its numerous advantages and its new powerful features. Meanwhile, this control system is also in operation at the Penning trap mass spectrometers SHIPTRAP [9] and LEBIT [10].

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